MAGNETIC AMPLIFIER ANALYSIS FOR ALTERNATING-CURRENT CONTROL

BY

SACHINDRA MOHAN SEN

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MAGNETIC AMPLIFIER ANALYSIS FOR ALTERNATING-CURRENT CONTROL

There are many analyses in the literature of magnetic amplifier circuits with d-c control but no analysis has so far been attempted for a suitable magnetic amplifier circuit for a-c control. The reason probably is that an analysis with a-c control voltage becomes further complicated because of the increase in the number of circuit parameters, particularly in the control circuit, which now has a varying current. Also the phase of voltage on the control circuit with respect to load circuit is an additional complicating factor.

In the actual analysis, a circuit with a saturable reactor with two windings and with resistances and a-c voltage sources on both sides, together with a rectifier on the load side was taken and analysed. It is evident that the magnetisation characteristic invariably enters into any sort of analysis of a magnetic amplifier problem and a solution of such a problem becomes extremely difficult due to the actual non-linear and multivalued nature of the magnetisation curve, which cannot be represented by suitable mathematical equation. All analyses have, therefore, been based on neglecting the low hysteresis and eddy current losses and approximation of the actual curve either by straight line representation or by curves which can be approximated by suitable mathematical functions like hyperbolic, transcendental or polynomials. For this analysis, the magnetisation curve has been assumed as consisting of straight lines, one with steep slope and passing through the origin and the other with zero slope intersecting the other line with steep slope when the saturation flux is reached. The ampereturns necessary to obtain saturation flux is called critical ampereturns, i_k.

The problem has first been analysed assuming that the circuit parameters and voltages are chosen in such a way that the control ampereturns is never large enough to saturate the core by itself. Under this condition assume, that at certain instant the core is saturated and the currents follow the respective voltage waves till

the total ampereturns decreases to the critical value i_k. At this instant the core becomes unsaturated and the operation is in the region of the magnetisation curve with steep slope and the circuit behaves as a magnetically coupled circuit. During this transition the boundary condition for the matching of the currents in the individual loops is satisfied. At a later instant of the cycle the rectifier blocks as the current in the load circuit becomes zero. From this moment onwards there is no current in the load or rectifier circuit and the current in the control circuit is given by its own voltage divided by its own impedance together with a decaying transient component which is generated in the circuit and matches the value of current at the instant of transition. The next change in the circuit condition takes place when the rectifier starts conducting again; this happens when the voltage across the rectifier, which is the algebraic sum of the load circuit generator voltage and induced voltage from the control circuit, becomes positive. From this moment onwards the circuit behaves as a magnetically coupled circuit with currents in both the load and control circuits and the boundary conditions are matched, the result being the generation of transient components in each of the circuits. The operation is now in the region of steep slope of the magnetisation curve. The next transition takes place when the total ampereturns gradually increases till it becomes equal to the critical value i_k. At this instant the core becomes saturated and the currents in each of the circuits shoot up and follow the respective voltage waves. Thus one cycle of current is completed, and the currents repeat henceforth. During one complete cycle four different transitions take place and circuit condition changes each time. Now knowing the currents it is possible to determine power gain and other relevant features of the amplifier.

When the control ampereturns is allowed to have any value, in other words if the values of the circuit parameters are such that the control ampereturns is greater than the critical ampereturns for some part of the cycle the analysis is no different but it needs careful attention in individual cases; the difference is that the switching processes from one circuit condition to another do not

follow one after the other in the same order as in the previous case but the order of transitions may be interchanged.

On the basis of the theory outlined above computations of currents and power gain have been carried out for different values of circuit parameters and magnitudes and relative phases of the load and control voltages. The results were checked experimentally within the limit of expected errors.

From the theoretical computations based on the analysis developed and also the experimental data obtained one is led to make the following further comments:

(a) Not only the magnitude but also the relative phase of the control voltage has a decided effect on the behaviour of the amplifier. It has been found, both from theoretical and experimental considerations, that the load current is a maximum for the control voltage leading phase angle of 150^0.

(b) The load current is minimum for a control voltage leading phase angle of 330^0.

(c) Again, the control current is maximum for a control voltage leading phase angle of 240^0.

(d) Further, the rate of change of load current with magnitude of control voltage is maximum around a value of control voltage leading phase angle of 330^0 suggesting this angle for maximum control of amplifier load current. Also there is a maximum of rate of change of load current with control current for a control voltage leading phase angle of 30°. Hence this angle is recommended for obtaining maximum variation of power gain with relative phase angle.

(e) With d-c control in a magnetic amplifier a steady premagnetisation flux can be effective in a core whereas with a-c control the flux due to control ampereturns alternates and is not effective in causing saturation during the complete period of a cycle. Hence it would be expected that a smaller magnitude of d-c control voltage is more effective in controlling the load current as compared to the effectiveness of a-c control voltage.

For the same reason a larger power gain can be obtained with d-c control than with a-c control. A power gain of 500 is common with d-c control whereas in this study a power gain of 56·8 has been calculated and a power gain of 38·3 has been obtained from experimental data for a-c control. However, it must be remembered that the usefulness of a-c control comes in when the available control voltage is alternating.

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